THE ENERGY OBSERVER

Energy Efficiency Information for the Facility Manager

Quarterly Issue – September 2007

Electric Motors

The Energy Observer summarizes published material on proven energy technologies and practices, and encourages users to share experiences with generic energy products and services. This quarterly bulletin also identifies informational sources and energy training for facility managers and staff. ***The Energy Observer*** is a service of the **Energy Office, Michigan Department of Labor & Economic Growth.**

This issue of The Energy Observer focuses on electric motors, in particular those used in commercial and institutional buildings, and their inherent energy efficiency issues. An electric motor is an electromechanical device that uses the attracting and repelling forces of magnets to create motion. There are many types of electric motors, some smaller than a human hair, others large enough to power a locomotive. The types of motors that will be discussed in this issue work on alternating current and typically range in size from 1/4 horsepower up to 5 horsepower.

Background/Basics

Motors are used for many purposes including heating, cooling, pumping, and to drive mechanical devices.

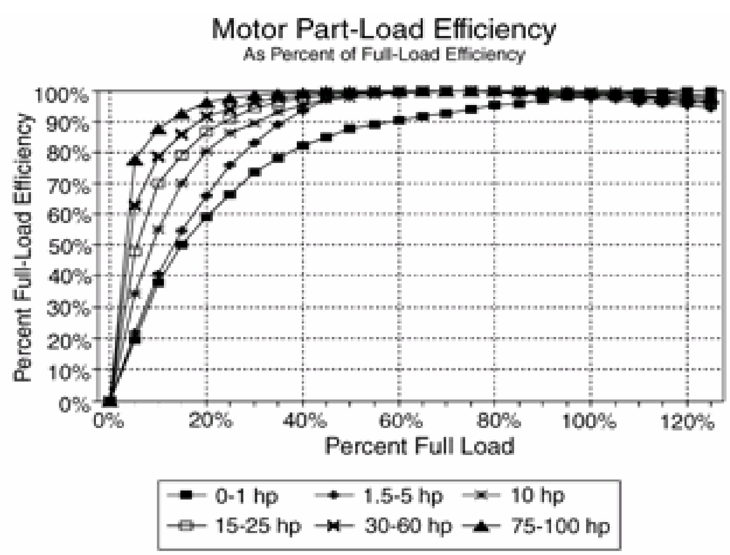
The fundamental principle upon which electric motors are based is that there is a mechanical force on any current-carrying wire contained within a magnetic field. The force is perpendicular to both the wire and the magnetic field. In a motor, the rotating part (usually on the inside) is called the *rotor*, and the stationary part is called the *stator*. The rotor rotates because the wires and magnetic field are arranged so that a torque is developed about the rotor's axis. The motor contains electromagnets that are wound on a frame. Though this frame is often called the armature, that term is often erroneously applied. Correctly, the armature is that part of the motor across which the input voltage is supplied. Depending upon the design of the machine, either the rotor or the stator can serve as the armature.

Loads and Energy Efficiency

Motor efficiency is the ratio of mechanical power output to electrical power input. It is the representation of the percent of input energy that is converted into useful work. The horsepower required to drive a machine is typically referred to as motor load. The equation for horsepower based on torque and rotational speed is:

$$\text{Hp} = \frac{\text{rpm x torque}}{5{,}252}$$

A motor's nameplate rating is based on the output power it can produce at full load over a given time period without overheating. As seen in the graph below, motor efficiency varies with load. The efficiency of motors usually peaks at close to 75% of full load. Oversized motors generally operate at a lower efficiency. For example, a motor that is operating at 35% load is less efficient than a smaller motor that is matched to the same load. Therefore, sizing a motor correctly is very important to not only prevent overheating but also to achieve maximum



energy savings.

Proper Sizing

Loads fall into three categories: constant torque loads, variable torque loads, and shock torque loads. Constant torque loads are machines such as centrifugal compressors and extruders that have relatively constant torque requirements. After reaching a steady state load, their torque demand varies no more than a few percent. To size a motor for this kind of application, match the motor output rating to the load's torque converted to horsepower.

Variable-torque applications, such as centrifugal pumps and fans, have a load that varies slowly, and often over a range of 20-100%. For these types of loads, size the motor for the highest continuous load.

Shock torque loads can vary abruptly in equipment like saws, compactors and punch-presses. As the load increases rapidly the motor slows slightly producing more torque. If the change is extreme, the load may exceed the motor's breakdown torque causing a stall. So choose a motor with a high breakdown torque to keep the machine from stalling.

Efficiency Type	Data	Horsepower							
		5	7.5	10	15	20	25	30	50
Standard Efficiency	Efficiency at 75% Load	84	86	88.4	89.3	90.8	90.9	91.6	91.8
	Annual Consumption (kWh)	24,978	36,595	47,469	70,486	92,428	115,408	137,432	228,554
	Annual Cost ($)	$1,499	$2,196	$2,848	$4,229	$5,546	$6,925	$8,246	$13,713
NEMA Premium Efficiency	Efficiency at 75% Load	90.7	91.9	92.4	92.6	93.1	93.6	94.4	94.9
	Annual consumption (kWh)	23,133	34,246	45,414	67,974	90,145	112,079	133,355	221,088
	Annual Cost ($)	$1,388	$2,055	$2,725	$4,078	$5,409	$6,725	$8,001	$13,265
	Annual Savings (kWh)	1,845	2,349	2,055	2,512	2,283	3,329	4,077	7,466
	Annual Savings ($)	$111	$141	$123	$151	$137	$200	$245	$448
	List Price ($)	$533	$724	$814	$996	$1,294	$1,700	$1,771	$2,751
	Purchase Price ($)	$426	$579	$651	$797	$1,035	$1,360	$1,417	$2,201
	Payback (years)	3.9	4.1	5.3	5.3	7.6	6.8	5.8	4.9

Premium Efficiency Motors

Energy typically accounts for over 97 percent of a motor's total costs over the course of its operating lifetime. However, the purchase of a new motor often tends to be driven by a short-term fixation on price, not the long term electricity costs. A little more money upfront for a more efficient motor is usually paid back quickly with significant energy and cost savings.

In the motor marketplace, three terms are used to label motors: "high-efficiency", "energy-efficient", and "premium-efficient". Only the last two terms have definitions established by the National Electrical Manufacturers Association (NEMA). Despite a higher initial cost, energy-efficient motors offer substantial energy savings and other benefits. They are usually higher quality, more reliable, last longer, have longer warranties, run quieter and cooler, and are more suited for use with a variable frequency drive (VFD). The chart above is a comparison of standard efficiency motors to NEMA Premium-Efficiency ones.

More information about electric motors can be found at these web-sites:

http://www.geaps.com/proceedings/2005/obrien.cfm

http://www.motorsmatter.org/case_studies/index.html

http://www.nema.org/gov/energy/efficiency/premium/

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